THE COPPER SILVER VEINS OF THE TELKWA DISTRICT, BRITISH COLUMBIA.

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CONTENTS.

INTRODUCTION.

The following is a brief summary of some of the results which were obtained by the writer in an investigation of the geology and mineral deposits of the Telkwa district. The field work was done during the season of 1915 under the direction of the Geological Survey of Canada. This work was supplemented by a considerable amount of petrography and mineralography carried on in the laboratories of the Massachusetts Institute of Technology and under the very helpful and inspiring supervision of the geological staff.

LOCATION.

The region in which these veins occur comprises approximately 40 miles from east to west and 22 miles from north to south, and is situated so that the northeast corner lies a few miles south of the town of Telkwa, on the Grand Trunk Pacific railway, at a point about 300 miles east of Prince Rupert. The only means of communication between the interior parts of the district and the railroad are two wagon roads and a number of trails.

TOPOGRAPHY.

The country is mountainous, lying about on the boundary of the two physiographic provinces known as the Coast Range system and the interior plateau. It is bounded on the west by a rugged spur of the Coast Range and on the east by the broad valley of the Bulkley River. In the centers of the east and west halves of the area are two similar and roughly circular groups of mountains, separated from each other and from the Coast Range by deep glacial valleys of the type known as "through valleys." These valleys cut sharply into the gentle slopes of an old mature erosion surface and have the peculiarity of extending through to adjoining drainage systems with very low divides, usually flat and marshy. Each of the two mountainous areas reaches an elevation of about 8,000 feet, and the Coast Range rises to about 9,000 feet. The Bulkley valley in this district is below 2,000 feet. Each of the mountain masses has radial drainage and the streams occupy deeply cut glacial valleys which head in cirques, many of which are still occupied by active glaciers. The cirques extend well back to the center of mountains in many places being separated only by sharp arêtes, indicating that the glacial cycle of erosion has developed to a mature stage.

GEOLOGY.

The geology of the area is directly related to the topography since each of the three mountainous areas has at its core an intrusion of plutonic rock, which cuts through the old tuffs of the Hazelton formation.

The oldest rocks of the district make up the Hazelton formation, which is thought to be Triassic or in part Jurassic in age. The formation has an areal distribution of many thousands of square miles in northern British Columbia, and a total thickness estimated by Dawson to be not less than 1,000 feet. With the exception of a small thickness of sandstone and shale containing a minor amount of coal, the entire formation is composed of volcanic rocks, and of this, 95 per cent. of the thickness, exposed in the Telkwa district, consists of tuffs. These tuffs are characteristically red in color, and vary in texture from coarse breccias with fragments up to a foot in diameter to an extremely fine cherty rock whose nature could not be determined without the aid of strong magnification. The prevailing texture, and the one which was responsible for the formation being called by Dawson the "porphyrite group," consists of a fine, reddish, hard groundmass plentifully sprinkled through with conspicuous white feldspar crystal fragments averaging about 3 millimeters in length.

The chemical composition of the rock is about that of an andesite. It consists mainly of small glass fragments in various stages of devitrification and containing many minute particles of hematite. These are cemented with a siliceous matrix also containing a high proportion of hematite powder which gives the rocks their characteristic color. No ferromagnesian silicates are present excepting a considerable amount of secondary chlorite. At the contacts of the recent intrusions the tuffs are metamorphosed for distances from the contact up to a mile. The chief alteration has been the development of a large amount of very pale green biotite, a considerable amount of sericite and silica, and the change of hematite to magnetite thus changing the color from red to black. These rocks underlie nearly the whole of the district excepting the small areas occupied by the later intrusions.

The oldest intrusive rocks are those of the Coast Range batholith thought to be of Jurassic age. They form the main body of the Coast Range in this district and also the small stock-like intrusion composing the core of the eastern of the two mountainous areas mentioned above, known as the Telkwa Mountains. The rocks of these two localities are practically identical in composition and appearance. They are quartz diorites and granodiorites having a medium coarse texture and a light gray color.

Younger than these, and cutting sediments of known Cretaceous age outside the district here considered, are many small intrusions forming sills and dikes, which Leach has grouped together into what he calls the Bulkley intrusives. These intrusions are of two different rock types, acid members of a peculiar composition, being high in soda, low in potash and medium high in silica; and basic members lamprophyric in composition. In hand specimen the acid type has a reddish pink color, and is seen to be composed of a close aggregate of pink tabular feldspar phenocrysts, uniform in size, having an average length of 4 millimeters evenly distributed in a scant light gray groundmass, sprinkled with small grains of iron oxide. Under the microscope the phenocrysts were found to be albite, and their pink color is due to abundant decomposition products, mainly hematite. The groundmass consists of quartz, sericite, orthoclase, chlorite and hematite. The quartz is the most abundant, while the orthoclase is almost negligible in amount. The hematite forms pseudomorphs probably after amphibole.

This rock occurs only in the western half of the area where it forms the core of the western mountain group called the Star Mountains. It forms an exceedingly irregular mass with numerous long tongues or lobes projecting out in three dimensions. It would be difficult to classify it with any of the common types of injected bodies but it seems to fill all the conditions of Professor Daly's definition of a chonolith.

The basic members of the Bulkley eruptives occur in all parts of the area, usually but not always forming dikes, and have played an important part in the mineralization of the district. They contain such rocks as diabases, kersantites and odenites, diabases being the most common.

ECONOMIC GEOLOGY.

A considerable amount of mineralization has been produced along the contacts of all the above-described intrusions, and while no large ore bodies have as yet been discovered in the district, there are many small deposits, some of which are rich in copper, gold and silver. According to their geographical distribution, their geological associations and mineral composition, the deposits fall naturally into three groups, namely: those which lie close to the contact of the main Coast Range batholith; those near the contact of the intrusion which forms the core of the Telkwa Mountains; and those scattered over the district but always associated with one of the later Bulkley eruptives. Each of these groups has its own peculiar association of minerals and structure, but in several instances the same veins have come under the influence of mineralizing solutions of both the batholithic rocks and the Bulkley eruptives giving an ore of a very striking and unusual type.

THE VEINS LOCATED AT THE CONTACT OF THE COAST RANGE BATHOLITH.

These veins are of considerably less economic importance than the others and are represented by two small groups of claims situated south of Clear Creek in the northwest corner of the area. The veins are irregular in width and direction; in some places forming a tangled network of veinlets an inch or less in width and in others forming large lenticular bodies 15 feet wide. The longest of these veins was traced for 1,500 feet.

The gangue consists almost entirely of milky quartz with small inclusions of highly silicified country rock. A slight tendency to banding can be detected. Small vugs, a few centimeters in size, occur plentifully in the quartz, and contain small crystals of quartz and of brilliant pyrite.

The ore of these veins consists of large masses of galena with small segregations of chalcopyrite, often containing crystals of quartz 5 to 6 centimeters in length. Under the metallographic microscope, besides the galena and chalcopyrite, zinc blende, minute quantities of argentite, tetrahedrite, covellite, and hematite were seen. The galena forms about 90 per cent. of the ore, and the chalcopyrite the larger part of the remainder. The chalcopyrite occurs as small, irregularly shaped grains in the galena with smooth, rounded contacts, which suggest simultaneous deposition. The argentite is also found in the galena but in very small blebs, often situated at the points of the irregular grains of chalcopyrite. The tetrahedrite occurs in only microscopic amounts, and is seen as small rounded areas in the galena with smooth contacts which indicate a probable simultaneous deposition.

All the minerals are cut by small veinlets of limonite, along some of which were seen a little covellite. The smooth contacts of some of these veins undoubtedly indicate replacement, but others have sharp, angular contacts which show that they occupy cracks formed by crushing of the ore. Malachite and azurite are present in small amounts.

The alteration of the country rock is intense. The tuffs are changed to a light green, fine-grained rock somewhat like propylite, containing visible grains of quartz and pyrite. Under the microscope it is seen to consist almost entirely of about equal amounts of chlorite and sericite with a little epidote in a fine-grained mass of quartz. In this groundmass are enclosed corroded crystals of quartz which are probably primary, and have been partly replaced by sericite and chlorite. Later than all these minerals are numerous small veins of quartz. The granodiorite is altered to sericite, quartz and chlorite, and slightly impregnated with pyrite.

The order in which the minerals were deposited, as indicated by the veining of the earlier by the later minerals, is as follows:

$$\text{I.}\begin{cases}\text{Epidote,}\\ \text{Sericite,}\\ \text{Chlorite,}\\ \text{Quartz.}\end{cases}$$

$$\text{II.}\{\text{Quartz (gangue).}$$

$$\text{III.}\begin{cases}\text{Pyrite,}\\ \text{Zinc blende,}\\ \text{Chalcopyrite,}\\ \text{Galena,}\\ \text{Tetrahedrite,}\\ \text{Argentite.}\end{cases}$$

IV. { Limonite,
Covellite,
Azurite,
Malachite.

The proximity of these veins to the batholith, their association with the altered volcanics which persist along the contact, and their extension into the granodiorite itself are considered as strong evidence that the veins are derived from solutions which emanated from the intrusion. The presence of gold and silver with lead, copper, antimony and zinc; the association of pyrite, galena, chalcopyrite, tetrahedrite and zinc blende; the absence of any large amounts of arsenic, molybdenum and such oxides as magnetite, hematite and ilmenite or such silicates as biotite, pyroxene, amphibole and tourmaline, and the general simplicity of the deposit are all evidence that these veins were formed by heated solutions at intermediate depths.

THE VEINS SITUATED IN THE VICINITY OF THE GRANODIORITE INTRUSION AT THE CORE OF THE TELKWA MOUNTAINS.

The deposits of this group contain much more copper and silver than those of the first, and include the most promising claims of the district. Besides their greater economic value, they also possess a greater scientific interest because of the complexity and singularity of their mineral associations and types of structure.

The group consists of ten or more slightly developed claims. From three of the number, enough ore has been extracted from small tunnels and open pits to make smelter shipments.

The situation of these deposits bears a direct relation to the contact of the granodiorite intrusion, in that they form a ring around the stock, none of them being farther than 1½ miles and none nearer than a mile. They are also situated just outside of a zone of intense metamorphism which surrounds the stock. Almost all the claims are at an elevation of about 6,000 feet and all happen to be exposed just where the steep walls of the glacial valleys intersect the gentle slopes of the old upland.

The deposits are characterized by an abundance of bornite, chalcopyrite, chalcocite, hematite and tetrahedrite, associated with epidote and quartz.

There are two types of deposits, those consisting of small replacement bodies disseminated through a porous and highly epidotized bed of tuff, usually more highly concentrated along joint fissures which cut the bed vertically; and those which are clearly open fissure fillings, with well-defined walls, and a gangue of banded quartz.

The Replacement Type.

The best example of the replacement ore bodies is the Excelsior claim in Dominion basin, one of the most promising deposits in the district. The mineralized bed of tuff outcrops on the nearly vertical wall of the basin at an elevation of 5,750 and 300 feet above the bottom of the basin. This bed, which is highly altered and carries a large amount of bornite, chalcopyrite and chalcocite, is interbedded with the typical unaltered tuffs of the Hazelton formation. The strata dip about 18 degrees to the south, away from the contact. Near the south end of the outcrop the tuffs are cut at nearly right angles by a 20-foot diabase dyke which carries a small amount of chalcopyrite and a large amount of magnetite.

The tuffs adjoining the mineralized bed are purplish, dense, fine-grained rocks with conspicuous crystal fragments of feldspar up to a centimeter in length, and are typical of most of the tuffs of the Hazelton formation. Close to the ore-bearing bed they are highly impregnated with epidote, and near the ore shoots contain a considerable amount of bornite and chalcopyrite.

The Mineralized Bed.—The bed which carries the copper is an unusual rock both in appearance and composition, due to its nearly complete alteration to hornblende and epidote. The most normal phase, or that which is encountered at a distance from the ore shoots, is a yellowish-green rock, containing in a dense, fine-grained groundmass, phenocrysts of green, fibrous hornblende up to 3 or 4 millimeters in diameter. Under the microscope it was found to consists entirely of epidote and hornblende in about equal amounts, with a very few grains of hematite, and a great number of small pores. The groundmass consists of small, rounded grains of epidote in a mesh of fine actinolite needles. The amphibole is a dull grayish-green color in hand specimens and in thin section is a pale, slightly bluish-green with an indistinct pleochroism. It has a marked fibrous structure with positive elongation, negative double refraction, and an extinction on the fibers of 10 to 20 degrees.

Adjoining the ore shoots, the rocks contain, in addition, garnet, a little quartz, more hematite and magnetite, and a dark-greenish calcite apparently colored by a fine network of actinolite fibers.

Under the microscope no other minerals were seen. The epidote, which forms about 50 per cent. of the rock, or more, occurs as phenocrysts about 2 or 3 millimeters in length, and also as a close aggregate of small round grains a fraction of a millimeter in diameter. The fibrous hornblende is not so plentiful as in the rock farther from the shoots, and does not occur as phenocrysts but forms a large portion of the groundmass. Grains of quartz were observed in the sections filled with fine, hair-like crystals of actinolite. The garnets are the next most plentiful mineral after hornblende. They form grains several millimeters in diameter showing a slightly yellowish color, and always a strong anomalous double refraction. Magnetite, like calcite, is a late mineral and is found in veins cutting through the rock and as crystals in open vugs.

The Ore.—The ore occurs in shoots, extending across the beds almost at right angles, and often penetrating the adjoining beds. They have flat, elliptic outlines, with the major axis vertical, when sectioned perpendicular to the bedding, and have an average width of about 6 feet. Their size is, however, somewhat variable and they are not regularly spaced. They are shown in Fig. 48.

The centers of the shoots are composed of a band of almost solid bornite irregularly replacing the epidote more or less completely for a width of several inches. The limits of these bands are not clearly defined, the bornite simply becomes more sparsely disseminated with increasing distance from the centers until no ore minerals can be seen without the aid of a microscope. In the leaner parts of the ore shoots, chalcopyrite becomes evident and with the bornite shows a tendency to occupy small rounded cavities about the size of the phenocrysts of the unmineralized portions of the bed. The boundaries between the sulphides and epi-

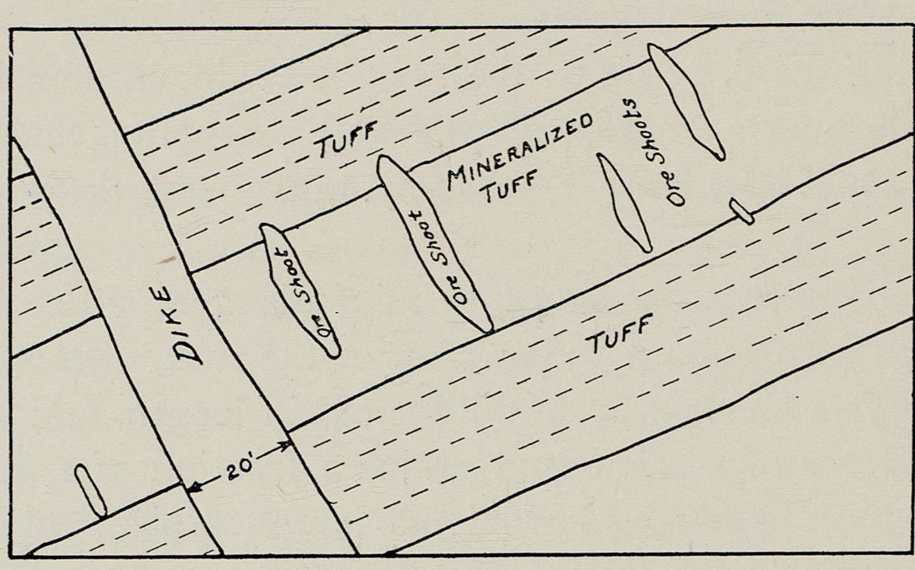

FIG. 48. Section of ore bed of Excelsior Claim.

dote are in all cases extremely ragged. No sharply bounded veins are found in the ore.

The study of the polished sections reveals chalcopyrite, bornite, chalcocite, zinc blende, galena, covellite, hematite, magnetite, limonite and ilmenite.

Bornite constitutes about 75 per cent. of the sulphides present. It forms in places solid streaks up to 2 inches in width extending along the shoots for many feet, and is also plentifully distributed in the disseminated ore.

Considerable chalcocite is intimately associated with the bornite. It is of a dull grayish-blue variety, often showing streaks of a lighter color, arranged in a reticulate pattern. It forms mutual contacts with the bornite, and the graphic intergrowth is exceedingly common. Many places were found in the polished sections where the bornite after forming a narrow, regular rim between the chalcocite and the gangue would branch into the chalcocite forming a true graphic structure. The reverse of this was also found where the chalcocite formed rims and branched

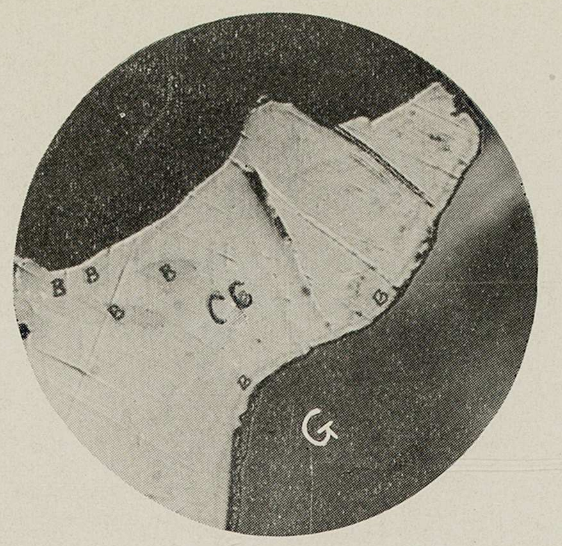

FIG. *A*.

MAGNIFIED 64 DJAMETERS.

Chalcocite rimmed with bornite, which also develops into the "graphic structure." *CC*, chalcocite; *B*, bornite; *G*, gangue.

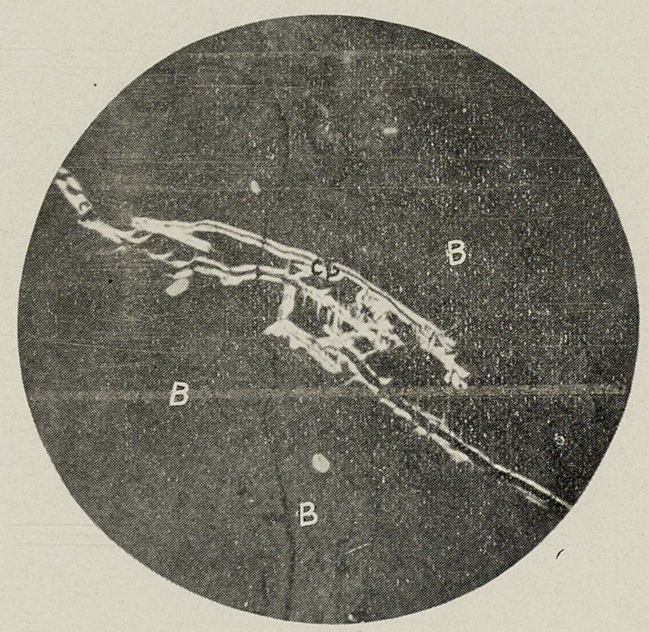

FIG. *B*.

MAGNIFIED 63 DIAMETERS.

Bornite replaced by veinlets of chalcopyrite and chalcocite. *B*, bornite; *Cp*, chalcopyrite.

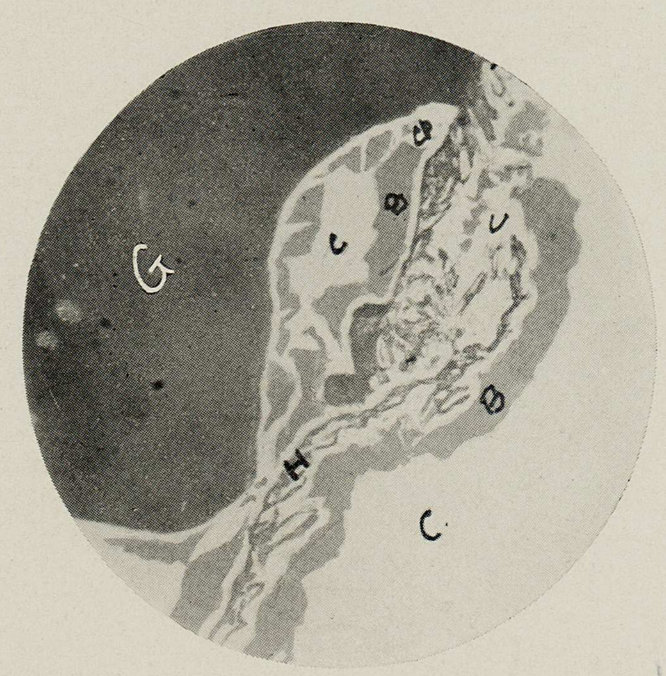

FIG. *C*.

MAGNIFIED 2,000 DIAMETERS.

Bornite and chalcocite replaced by hematite and chalcopyrite. *H*, hematite; *G*, quartz.

FIG. *A*.

MAGNIFIED 390 DIAMETERS.

Bornite and chalcocite replaced by chalcopyrite and chalcocite. The late chalcocite lines the chalcopyrite vein labeled *Cp*. *B*, bornite; *Cp*, chalcopyrite; *G*, galena; *Q*, quartz.

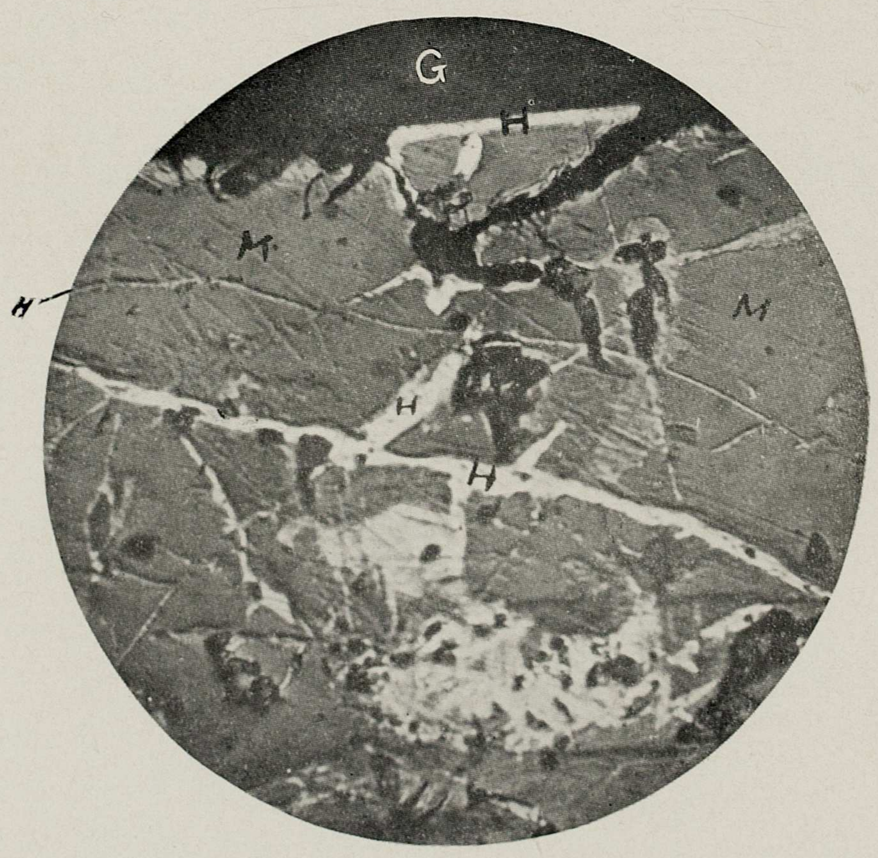

FIG. *B*.

MAGNIFIED 425 DIAMETERS.

Magnetite replaced by hematite. *M*, magnetite; *H*, hematite; *G*, gangue.

into the bornite. The former relation is shown in Plate XXIII., *A*. The contact between the two minerals in many places is not sharp but the one color fades out very gradually into the other, forming a mixed zone. Besides this chalcocite there is some of a distinctly secondary nature which follows minute fractures cutting through the bornite-chalcocite intergrowths. Where the fracture traverses bornite areas it is lined with this secondary chalcocite, and where it crosses the chalcocite, covellite is deposited. These veinlets frequently have chalcocite centers and chalcopyrite margins, as shown in Plate XXIII., *B*.

Chalcopyrite occurs sparingly in all the specimens and like the chalcocite is of two generations. It occurs as a primary mineral in the gangue sometimes occupying spaces which were originally phenocrysts, and also in the bornite where the smooth rounded contacts, and mutual intergrowths indicate a contemporaneous deposition with that mineral.

It also commonly occurs in a distinctly later generation, and frequently forms extremely narrow but persistent borders between the bornite and the gangue, or between the bornite and the hematite, in places penetrating the bornite along minute fissures. These fissures often contain chalcocite in their centers and cut independently both chalcocite and bornite. The replacement has not gone far but numerous small spikes of chalcopyrite can be seen shooting out into the bornite along crystallographic lines as if an early stage of the lattice structure were being developed. This is shown in Plate XXIII., *B*; the white mineral is the chalcopyrite. Plate XXIV., *A*, shows one of these veinlets cutting across a bornite area into an area of chalcocite.

Galena is sparingly present and is found only in the bornite and bornite-chalcocite graphic structures, where it forms small blebs or more often fine films appearing as almost submicroscopic lines in the polished sections. These films are usually arranged in one definite direction, and are probably controlled by the cleavage of the bornite. Their arrangement is, however, only approximately maintained and the thickness is also quite variable. They have no connection with any fractures and are undoubtedly of primary origin. A small bleb of galena is shown in Plate XXIV., *A*.

Zinc blende was found in only one specimen where it appeared as medium-sized grains, which contain numerous small specks of chalcopyrite, and in one case bornite.

Magnetite and hematite are, as usual, abundant. In some portions of the mineralized bed magnetite forms large veins, associated with quartz and epidote, or occurs in well-developed octahedrons on the walls of open cavities. Hematite is pentifully associated with the magnetite and has extensively replaced it along fine ramifying veinlets and also along regular crystallographic lines, in the latter case forming a reticulate structure. Veinlets often follow the line between the magnetite and the gangue. The replacement of the magnetite is shown in Plate XXIV., *B*. Hematite is more plentiful in the ore than in the wall rock and greatly exceeds the amount of magnetite. It is replaced by hematite and sulphides; grains of it are frequently seen coated with a shell of bornite, or chalcocite, or both. The hematite on the other hand replaces the sulphides and very faithfully follows the contacts between the sulphides and gangue.

Calcite is later than the hematite and other minerals, and occupies small veins irregularly cutting the ore. It is, also, found in veinlets following the contact of the hematite and epidote. A vein of this calcite is shown in Plate XXIII., *A*, as a black line between the gangue and the sulphides.

Paragenesis.—As well as can be made out from the structures seen in polished sections the order of deposition of the minerals is as follows:

$$\text{I.}\left\{\begin{array}{l}\text{Epidote,}\\ \text{Hornblende and actinolite,}\\ \text{Quartz,}\\ \text{Hematite.}\end{array}\right.$$

$$\text{II.}\left\{\begin{array}{l}\text{Zinc blende,}\\ \text{Chalcopyrite,}\\ \text{Bornite,}\\ \text{Chalcocite,}\\ \text{Galena.}\end{array}\right.$$

III. { Magnetite, Hematite, Chalcopyrite.

IV. { Chalcocite, Covellite, Calcite.

The sequence in each separate group is not to be inferred from this arrangement for in each of the four periods some or all of the minerals were deposited simultaneously, or the order alternated from one sequence to the other. This is particularly true of the second group in which the order of the bornite and chalcocite is reversed from bornite-chalcocite to chalcocite-bornite, and it is clear in other places that both minerals were being deposited simultaneously. The relations of the chalcopyrite and bornite in this group indicate a contemporaneous deposition for some, and a later deposition for other portions of it.

Genesis.—The processes which brought about this complicated and apparently unusual sequence of mineralization are believed to have taken place as follows:

After the intrusion of the granodiorite stock, the adjoining tuffs suffered an intense thermal and hydrothermal alteration, producing a metamorphic zone extending half a mile or more away from the contact in all directions. This metamorphism was characterized by silicification, biotitization, with the dissemination of epidote, copper and iron sulphides, and a little silver. In certain porous beds a large amount of hornblende was produced, with epidote, magnetite and hematite. In these beds the mineralizing solutions and vapors were able to travel faster and thus produce a more intense alteration and to develop it farther from the contact than in the less porous beds. The first and hottest heat waves to pass off from the intrusion produced the metamorphic zone, and seemed to have the effect of closing any fissures which may have existed, for there were no veins of any kind seen in this zone. Beyond this, many fissures remained open, forming channels along which the solutions flowed and deposited the minerals which now form the richer veins of the district.

The minerals produced in this period were epidote, hornblende, actinolite, quartz and a small amount of magnetite and hematite.

Following this, came a period of mineralization at a much lower temperature, which deposited the zinc blende, chalcopyrite, bornite, galena and chalcocite and produced much chlorite in the tuffs.

Then came a period of igneous activity in which the late dikes were intruded, followed by a second period of high temperature mineralization which produced the hematite, magnetite and chalcopyrite, which characterize this period of mineralization throughout the district.

Much later than this, a slight amount of surface oxidation and enrichment has taken place, developing the covellite, chalcocite and calcite.

The Open Fissure Type.

This type of deposit is represented by five principal deposits: the High Grade, the King and Rainbow, and the Hunter, Idaho and Colorado.

The first two are the most valuable, and because they were affected by both periods of mineralization are much more complex than the others. They will be described separately. The other three, which are less important and more simple, will not be described in this paper.

The High Grade.—This claim contains the highest grade ore to be found in the district, and though rich in copper and silver, unfortunately is not plentiful, and being remotely situated, is not, under present conditions, worth the cost of its transportation.

The claim is located at the top of the high, steep wall of a large glacial valley occupied by Sunset creek, and is slightly more than one and one half miles southwest of the contact of the granodiorite stock. The cliff is almost perpendicular and well exposes the thin-bedded, bright red tuffs for a vertical distance of 150 feet below the upland plain which intersects the valley wall at an elevation of 6,000 feet.

Cutting the tuffs and striking in a southerly direction are two dikes of diabase, one about 15 feet in width is situated 100 yards to the east, and a smaller one outcrops 30 feet below the tunnel and on the east side.

Structure.—The tuffs here are folded into a low anticline with dips of about 20 degrees, and a plunge to the south of about 8 degrees. Almost on the axial plain of the fold the beds are ruptured along an irregular fissure, and it is in this that the mineral has been deposited.

This vein is exposed at intervals from the top of the cliff down to the edge of a glacier below, but owing to the thin deposit of soil cannot be traced along the surface of the plain. About 20 feet above the glacier the tunnel penetrates the cliff for about 20 feet along the vein. A few tons of ore were extracted from the tunnel, and samples taken from the ore dump assayed: gold, 0.03 oz.; silver, 27.6 oz.; copper, 18.8 per cent. The vein varies from 1 inch to 12 inches in width with a general vertical dip. In places on the outcrop it breaks up into a number of lenses separated from one another and only roughly following a linear arrangement. What appears to be on offshot of the main vein can be traced for 30 feet up the cliff above the tunnel to the west of the main vein, and has a dip to the east of about 70 degrees. The walls of the vein are sharply defined and little changed.

The Ore.—The ore consists of almost pure chalcocite in a gangue of quartz; the only other minerals which can be seen in the hand specimen are a little native silver, hematite associated with epidote, calcite, and a very small amount of malachite, azurite and laumontite. The chalcocite appears to be equal to or even to exceed the amount of quartz, and gives the ore a white silvery appearance which to the eye suggests much higher values than the assays give.

In general the ore is massive, and has an even medium-grained texture, but in places comb structure becomes evident. In other places the quartz forms small rosettes of radiating euhedral crystals. The epidote is confined to a narrow band along the east wall about an inch in width and to much smaller veinlets penetrating the more central parts of the vein. The hematite is closely associated with the epidote.

The microscopic study of the ore showed that bornite, argentite, chalcopyrite, covellite and hornsilver are present, besides the minerals already named.

The chalcocite is of two kinds, a pure white variety, which forms the bulk of the ore, and a bluish form, which is present in only small amounts. The white chalcocite is quite homogeneous, and when etched is seen to be formed of rounded but distinct crystals closely fitted together in small spaces in the quartz. It clearly replaces the quartz, in some places forming small veinlets and rounded shapeless masses, but it undoubtedly also fills many spaces, which were once empty cavities, the crystal outlines of the quartz being still preserved. Some of the larger areas which have diameters up to three fourths of an inch occupy cvaities of this nature. Almost all of the larger areas have peculiar cracks crossing them, which fade out towards the margins and become wider at the center. None of them were seen to cross from one area of chalcocite to another and all were of this peculiar shape. The size of the cracks varies directly with the size of the grains in which they occur, those in the largest grains can easily be seen with a hand lens. They strongly suggest shrinkage cracks and are of constant occurrence. Some of them are filled with calcite or other gangue minerals, while many of them are empty.

The blue chalcocite is confined to the epidote areas and is frequently traversed by wide open cracks along which it is altered to covellite. In the epidote band on the vein wall there is much blue chalcocite in the form of rounded irregular grains not connected with any veins, and which are all cracked and altered to covellite. They seem to be residual grains which have been altered by the solutions which deposited the epidote. Simliar chalcocite was found in the calcite, but some of it appeared to replace it along small veinlets.

Bornite was observed in only one specimen, and here in microscopic amounts, but is said to have been rather plentiful since the time of the examination, in the small branch vein to the east and some 30 feet above the tunnel. The bornite, which was found in one of the specimens at hand, did not show its relation to the chalcocite and their relative ages cannot, at present, be learned. The unusual structure of this bornite is shown in Plate XXIII., *C*. A band of bornite of uniform width in a chalcocite field follows a vein of hematite faithfully but is separated from it by a narrower margin of chalcocite. It also shows a similar band of bornite following the gangue contact, and separated from it by a similar band of chalcocite. Small spikes of chalcopyrite project into the bornite; they appear as white in the figure. A probable explanation of the structure is that the bornite bands are residual remnants after the replacement of the rest of the bornite by chalcocite, these being protected from the replacing solution by the solution pressure of the iron of the nearby hematite.

Chalcopyrite does not occur in the ore excepting in the minute spikes just mentioned, and as a few stray grains in the quartz.

Native silver can be seen in all of the specimens of the ore in which calcite is present. The chalcocite is nearly always blue when near the native silver. It was never observed in contact with the white chalcocite and its age can only be determined indirectly. In one specimen it was replaced by hornsilver.

Argentite is only found surrounding the silver and is not plentiful. It is later than the native silver, and was also seen filling cracks in the chalcocite.

Malachite and azurite occur incidentally as secondary minerals.

Hematite, the characteristic and ever-present mineral in this district, is present in large amounts and is most plentiful where epidote and calcite occur, especially in the epidote band throughout which it is disseminated only in the form of small blades. Wherever the epidote has penetrated the ore, the hematite is closely associated with it, but it has itself penetrated much farther. Microscopically small veins of it are seen in every specimen. These veins (see in Plate XXIII., *C*) have a strong tendency to follow the chalcocite-gangue contacts. These lines probably offered the least resistance, and were, therefore, usually selected by the iron-bearing solutions, but one also finds the veinlets running across the chalcocite sometimes cutting off small peninsulas of the chalcocite which jut out into the quartz. Another habit of the hematite, and a difficult one to explain, is that of following the gangue contacts very regularly, but inside the chalcocite areas, and separated from the contact by a narrow border. Aggregates of it do not occur excepting near the epidote and calcite. It would appear from this that the hematite came in at the same time as the epidote, and some time after the formation of the quartz-sulphide vein.

No magnetite was seen in the ore excepting a few scattered grains near the margins of the veins.

Of the gangue minerals, quartz is the most important. It is unusually full of inclusions of transparent and opaque minerals. Some of them are undoubtedly hematite blades, but these are not sufficiently plentiful to color the quartz, and must, therefore, form a very minor portion of the inclusions. Many of the inclusions are filled with liquid, and contain movable bubbles. The inclusions are arranged in lines which are roughly parallel, but are not straight, and conform to no apparent system.

Epidote is next in importance among the gangue minerals. It forms a band an inch, or more in thickness, on the east wall of the vein which is yellowish-green color, and has a sugary texture. From this band numerous veinlets branch off irregularly into the ore. It is occasionally seen in euhedral crystals in the calcite, and is of an earlier period than the calcite.

Calcite occurs as irregular masses in the ore several inches, or more, in size, and also as veinlets cutting the quartz. It contains only blue chalcocite, the silver minerals, and copper carbonates, all of which replace it along cleavage lines.

Laumontite was found rather plentifully along the margins of the vein; it has a light pink color, and soon crumbled away when exposed to the air. It was seen in one of the thin sections and determined by its optical properties.

Alteration of the Country Rock.—The tuffs adjoining the vein are surprisingly little altered. The color is changed from a red to a slaty green, and chlorite, epidote, quartz and occasionally a little laumontite along the walls have been introduced. The alteration does not extend more than a few inches from the vein. Adjoining the dikes the alteration is more intense, and considerable silicification, and some epidotization with the introduction of considerable hematite, has taken place. No sulphides were seen in the dikes or near them.

Paragenesis.—The observed structural relations could all be satisfied if the minerals had been deposited in this order:

Quartz,
Bornite,
Chalcocite.

Epidote,
Hematite,
Calcite.

Silver,
Argentite,
Hornsilver,
Chalcocite,
Chalcopyrite,
Covellite,
Malachite,
Azurite.

There is no doubt that the quartz was the first mineral to be deposited in this vein, and the copper sulphides are so closely related that they must have followed very soon after, if indeed they were not deposited at the same time. Such a close and intricate intergrowth of quartz and sulphides is not often seen. The relative ages of the copper sulphides is not so certain, and there are two possible explanations: one that bornite, and perhaps chalcopyrite, were deposited by primary solutions, and were afterwards replaced by the chalcocite; the other, that the three sulphides were deposited as primary minerals at about the same time. The first view, though quite possible, is supported by no visible facts except that there is bornite present. It is, however, supported by theory founded on numerous observations made in other parts of the world, and is the explanation which would, for this reason, be accepted by those who believe that chalcocite is never a primary mineral. The primary theory, on the other hand, is in strict accord with the facts, and conflicts with nothing but theory. The subject will be more thoroughly discussed in a later paragraph.

The epidote, hematite and calcite are of a distinctly different age and due to solutions of a different nature and temperature. This is not only proven by their occurring in veins which cut the other minerals, but is also strongly suggested by the close association of these minerals, particularly hematite and epidote, and their entirely different habits from the sulphides. The invariable rule of the epidote being associated with blue chalcocite of a probable residual nature is also evidence that the epidote was deposited after the chalcocite. The calcite is later than the hematite and epidote.

The other minerals are found in the calcite usually replacing it along cleavage lines.

Genesis.—The point to be noted in discussing the origin of this deposit is the replacement of the chalcocite along small veinlets, by hematite with the association of epidote and calcite.

The succession of relatively low-temperature minerals followed by such high-temperature minerals as hematite, can only be explained by the theory of two periods of mineralization, as at the Excelsior claim. Moreover the composition of the later mineralizing solutions containing hematite, epidote and calcite is also very suggestive of the type always found associated with the later basic dikes, one of which is located within 30 feet of the adit from which the ore was taken.

The composition of the primary ore is not exactly the same as that of the other claims, which are believed to have derived their minerals from the same source, *i. e.,* the granitic stock, but the presence of so much native silver associated with the secondary minerals, indicates that some silver mineral must have been in the primary ore. In view of this, the only difference between this ore and that of the other deposits is a lower per cent. of iron, producing chalcocite instead of bornite, a difference not sufficiently important to shake the theory that the primary ore of this claim also came from solutions emanating from the granitic stock.

According to this theory, it matters not whether the chalcocite be considered as primary, or as secondary after bornite, and that the hematite followed the bornite-gangue contacts instead of the chalcocite-gangue contacts, but for reasons that will be given in a later paragraph the chalcocite is believed to be primary.

Primary Chalcocite.—One of the most disputed points in the current literature on economic geology, and at the same time a most critical point, is the question whether or not chalcocite is ever a primary mineral. It is conceded by all that it is a most common secondary product, and while a few believe that it may, in rare cases, be primary yet there are many who maintain that no case of the primary origin has yet been proven. It is, therefore, with some timidity that I claim for this chalcocite a primary origin, though the evidence seems to point strongly in that direction. The importance of the matter rests on the question, whether the mineral can be taken as a positive criterion for proving the ore in which it is found to have been enriched by descending meteoric waters.

Some of the strongest evidence against the enrichment theory for this ore comes from the relations observed in the Excelsior claim. The microscopic structures show fairly certainly that some of the bornite of the graphic structures is of later date than some of the chalcocite. Areas of chalcocite surrounded by narrow persistent rims of bornite which send sharp wedge-shaped spikes into the chalcocite cannot be explained in any other way, and such were seen in several cases. The bornite rims are often connected with the bornite of the graphic structure, as for example, in Plate XXIII., *A*. This being the case, then, if the chalcocite is secondary, the bornite must also be considered secondary. But there is no evidence to substantiate this, the bornite is often closely associated with the chalcopyrite, but there is no sign of veining or replacement along the gangue contacts, or indeed any structural evidence of secondary replacement. On the contrary their smooth, rounded contacts, and mutual intergrowths indicate a contemporaneous and a primary origin for both. The relation of the galena to the bornite is also indicative of the bornite being primary. The small scattered and rounded grains of galena in the bornite resemble very strongly the type of structure seen in zinc blende, which is not known to ever have had a secondary origin. The occurrence of bornite specks in zinc blende, and also in magnetite, is still further evidence in favor of its primary origin.

Aside from the chalcocite, there is no mineralogical evidence that secondary processes have played a part in the formation of this ore. Pyrite is entirely absent from the ore-bearing bed itself, and from any of the nearby country rocks, since it is confined to the metamorphic zone. And without this mineral or marcasite to supply the iron sulphates for lixiviation, it would be difficult to obtain enrichment in this type of deposit. Such minerals as chalcedony and opal, which are strongly indicative of enrichment processes, are not present.

In the case of this deposit, too, the geological conditions are very strongly opposed to the enrichment theory. Here is a bed only 20 feet thick, with a dip of only 18 degrees, buried under 1,250 feet of barren tuffs whose original thickness must have been much greater. It is exposed to the surface only on a vertical wall of a glacial cirque formed long since glacial time, and contains ore shoots of, in places, almost solid bornite and chalcocite. In the absence of a leached zone above, but instead, an overburden of 1,250 feet of barren tuffs, where could the enriching metal come from? Supposing this were a chalcopyrite deposit so enriched, and then consider the amount of copper which would have to be brought from the overlying rocks. Chalcopyrite contains 34.5 per cent. copper, and a unit volume of bornite and chalcocite in equal amounts, contains about 67 per cent. copper, therefore, since replacement takes place volume for volume, the replacement of chalcopyrite by a mixture of this kind, which is very similar to the present case, would involve almost doubling the original amount of copper.

There is also much good evidence for believing the chalcocite of the High Grade claim to be of primary origin.

The entire absence of any of the replaced minerals, excepting the almost inconsiderable amount of bornite, is in itself opposed to the theory of enrichment in this case.

The chalcocite for the most part is enclosed in small cavities in the quartz in a manner that would make it difficult for the replacing solutions to act freely enough for even a partial replacement.

There is an absence of any indication of enriching processes in many of the claims of the district, such as the King and the Hunter, both of which contain an abundance of bornite, the most sensitive of all minerals. This could hardly be expected if in the High Grade all the primary minerals were swept clean by enrichment solution.

The cracks, which occur in the chalcocite, as described in a previous paragraph, are of such a nature that they cannot be explained in any other way than to consider them as due to shrinking. According to the accepted notion of replacement of bornite by chalcocite, there is no change in volume, the chalcocite simply passively occupies the space left by the dissolving of the bornite. Nor have such structures been observed by the writer in the study of secondary chalcocite, and neither have they been described by other authors. It has been proven that there is an inversion point at about 91 degrees at which the orthorhombic form of chalcocite goes over to the isometric. This temperature is in all probability below the temperature at which primary chalcocite would be formed and we must, therefore, expect an inversion from one form to the other at the time the sulphide passed through that temperature. The volume change involved in this inversion has not been determined but from what is known of the other polymorphous substances one would expect the low temperature form to have the lesser volume. The inversion of small, rounded masses of chalcocite enclosed in quartz would inevitably produce such shrinkage cracks. If this assumption is correct, it ought to be a good criterion for primary chalcocite, not only in this instance, but in general, where the chalcocite is so related to the gangue that the decrease in volume would cause cracking.

It might be argued that the absence of chalcopyrite from this ore, when it is such a persistent mineral in all the other veins of the district, is evidence of enrichment having taken place, but its absence would naturally be expected since the primary solutions would of necessity be low in iron in order that chalcocite could be deposited with only a trace of bornite.

The native silver might be regarded as evidence of enrichment, but it is later than the calcite, which for the most part is later than the white chalcocite, though earlier than the blue chalcocite. It is, therefore, clear that it has been formed since the primary chalcocite was deposited. In both claims where native silver occurred, it was associated with malachite, which suggests that it came from tetrahedrite and it might just as well have been produced by the carbonated waters which deposited the calcite, as from any descending meteoric waters.

The King and Rainbow Veins.

The King vein is the largest one of a group of four, situated on the south side of Hunter basin at an elevation of about 6,000 feet, at a point where the topography is exceedingly rough and steep. The vein does not outcrop continuously throughout its length but there is a fairly good alignment of all the outcrops and workings and a rough continuity of strike which makes it probable that it is one vein.

The total length is about 1,000 feet. The profile of the vein, and the workings, are shown in Fig. 49, which represents a section through the center of the vein and parallel to the strike.

The width of the vein varies from 10 inches to 3 or 4 feet. The walls are sharply defined against the tuff country rock. In a few places a small amount of reddish hematite gouge was found along one or another of the walls. The walls stand nearly vertical, and the strike of the vein is at an angle of about 45 degrees to the strike of the bedding of the tuffs, which dip 18 degrees to the northeast.

The composition of the vein varies from place to place along its strike. At the farthest north pit the vein has a width of about 4 feet and consists almost entirely of banded quartz containing small lenticular cavities and horses of the country rock. Pyrite in the form of small cubes and pyritohedrons is freely disseminated through the quartz. Associated with the pyrite is an equal amount of arsenopyrite. Replacing these minerals and the quartz, is a fairly large amount of chalcopyrite and zinc blende, which appear to have been deposited almost simultaneously.

The ore of the King claim may, for purposes of description, be divided into the chalcopyrite-pyrite ore of the east end, bornite-chalcopyrite ore of the central part, magnetite ore of the

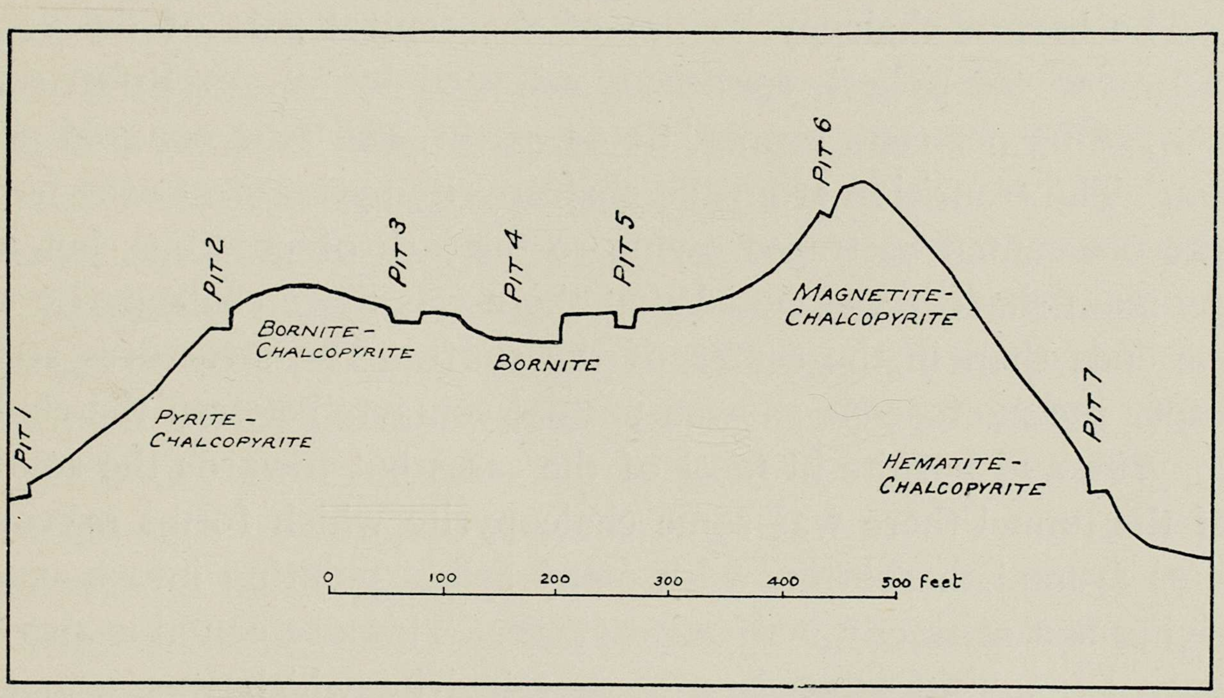

FIG. 49. Section parallel to King Vein.

middle south part, and the chalcopyrite-specularite ore of the western end (see Fig. 49).

The chalcopyrite-pyrite ore is the most plentiful of the four types, and is distinctly different in appearance and composition. It has a brassy color and is associated with a large amount of quartz. The pyrite grains are about one millimeter in diameter, fairly uniform in size, and rather evenly distributed in the quartz, but with a slight tendency to form bands. The arsenopyrite, the only arsenic-bearing mineral, occurs in grains of a similar size but is not so plentiful. The chalcopyrite is much more plentiful than the other minerals, forming about 70 per cent. of the sulphides present. It replaces the quartz extensively and also forms numerous small veins in the pyrite. These veins become so large and numerous in some of the pyrite as to leave only small skeletons of the original grains. Associated with the chalcopyrite, and intergrown with it in a manner strikingly similar to the graphic structure, is a large amount of zinc blende. It replaces the gangue and pyrite, and appears in every way to have been deposited with the chalcopyrite. The common rule for the sequence of these two minerals is for the blende to slightly precede the chalcopyrite, but no evidence could be found to prove that rule in this ore.

The bornite-chalcopyrite ore of the central part of the vein is by far the richest, specimens collected by W. F. Robertson assayed 63 per cent. copper, 81 oz. silver, and 0.04 oz. gold per ton. The transition from the chalcopyrite-pyrite ore to the bornite ore cannot be traced owing to the lack of outcrops, but in the main shaft it was noted that there was more chalcopyrite at the ends than in the center of the shaft. The structures seen under the microscope showed mutual contacts between the chalcopyrite and bornite in most of the cases but towards the south of the tunnel there was some chalcopyrite which forms narrow rims around the bornite with many spikes pointing into it, and giving it a distinctly later appearance. This ore contains also a large amount of silver-bearing tetrahedrite which was seen as rounded or elongated masses with smooth even contacts in the bornite and chalcopyrite, but with a preference for the chalcopyrite, or the contacts of the bornite and chalcopyrite. It was never seen in veins and is undoubtedly primary, having come in with the copper sulphides or in places slightly later than them. Magnetite grains become common in the eastern part of the main trench. They contain small veinlets of hematite which never go beyond the edges of the magnetite, and many of them are sprinkled over with numerous specks of chalcopyrite which grade down in size to submicroscopic. A few of these grains were composed of bornite, and some of the larger ones were slightly altered to covellite. Tetrahedrite was also found. No hematite outside of the magnetite grains was seen in this ore excepting a very few scattered blades and rounded grains in the quartz and other gangue. In some of the specimens there were some malachite and much limonite, indicating oxidation. Covellite is extensively developed along cracks in the bornite but is seldom seen in the chalcopyrite. The cracks in many cases proceed through the chalcopyrite but the solutions have produced no visible effect. This is an excellent example of selective replacement. Chalcocite is almost entirely absent from the King vein, and was seen in only one specimen, where it occurred along minute cracks in almost microscopically small amounts.

Magnetite ore begins to appear about 100 feet south of the main shaft, and the magnetite gradually increases in amount until, at the highest part of the ridge, the vein is almost solid magnetite, with a small amount of quartz. The magnetite is well crystallized when it occurs as small grains in the quartz, but the larger areas are irregular in outline and appear to replace the quartz. The smaller crystals are much more homogeneous than the large areas but contain small specks of chalcopyrite, bornite, and small veinlets of hematite, which are either confined to the crystal in which they occur, or to a narrow space along the margin. The larger areas of magnetite contain a great deal of hematite which appears to be of two generations. The larger amount is in the characteristic form of bundles or sheaves of narrow blades, often with a radiating habit. These blades are, however, extensively corroded, so that in the majority of cases there is nothing but a ragged skeleton left, with just enough hematite to suggest the original form. Besdies this, there is a considerable amount of hematite which occupies small veins cutting the magnetite, or surrounding it in the gangue contacts similar to the hematite in the small magnetite crystals. This is clearly later than the magnetite, and the hematite blades are just as clearly of an earlier date. All the magnetite is impregnated with chalcopyrite, bornite, tetrahedrite and probably some native silver, forming a structure which is remarkable if not unique. The sulphides are also disseminated in the gangue, but as larger grains. In both the gangue and the magnetite the copper minerals are slightly altered to covellite and secondary chalcopyrite and are replaced by limonite. Certain pseudomorphs of covellite, after bornite or chalcopyrite, contained a perfectly developed lattice structure, in which the covellite formed the background. These alterations indicate that considerable surface oxidation has taken place in this ore and it is believed that these processes have produced that part of the hematite which is clearly a late component of the ore.

The evidence favoring secondary hematite is unusually clear in these ores. The hematite veinlets are fine and persistent, following cracks in the magnetite as well as the margins of the grains, and do not exist apart from the magnetite. The existence of secondary hematite is gravely doubted by many eminent geologists and the question is a prominent one in current discussion on secondary enrichment.

The hematite-chalcopyrite ore found at the southwest end of the vein consists of a large amount of chalcopyrite and specularite with small amounts of bornite, tetrahedrite and magnetite. The striking feature of this ore is the large amount of specularite which forms veins 2 or 3 inches in width. The chalcopyrite occurs in massive veins and contains many small irregular areas of bornite with a little tetrahedrite. The chalcopyrite replaces the hematite blades rather extensively, cutting into their sides and often dividing them into irregular fragments. The bornite is in an advanced stage of alteration to covellite and chalcopyrite, the latter mineral forming an exceedingly fine lattice structure in many of the bornite grains. The chalcopyrite is completely fresh. The tetrahedrite is not noticeably plentiful, and is inclined to be located near the bornite. It seems to be of an earlier period than much of the chalcopyrite. Limonite is plentiful in this ore and can be easily seen replacing the hematite and chalcopyrite, and in places, the magnetite. The chalcopyrite is only slightly attacked and for the most part is conspicuously fresh. This part of the vein is also surprisingly rich. Specimens of the pure chalcopyrite collected by Galloway,[1] of the British Columbia Bureau of Mines, assayed: gold, 0.08 oz.; silver, 87.5 oz.; copper, 32.8 per cent. A sample of magnetite associated with bornite from the same opening assayed: gold, 0.20 oz.; silver, 25 oz.: copper,

[1] Galloway, J. D., "Mineral Resources of a Porton of the Omineca Mining Division," British Columbia Bureau of Mines, Bull, 4, 1915, p. 53.

25 per cent. A sample across the vein which is about 2½ feet wide assayed: gold, 0.14 oz.; silver, 26.9 oz.; copper, 14.6 per cent.

No other gangue than quartz was found in any part of this vein.

The alteration of the country rock immediately adjoining the King vein is comparatively slight. The tuffs have lost their reddish color to some degree and have become somewhat greenish. In polished sections they are seen to consist of fine-grained tuffs which have become silicified and chloritized with the introduction of a small amount of epidote. The sulphides have been disseminated in the adjoining rock in places somewhat plentifully. The tuffs show their usual amount of very fine-grained hematite and also some magnetite. As one follows the vein southwest from the main shaft there is a notable increase in the amount of epidote of the country rock, which increases still more in amount west of the pinnacle where the magnetite ore occurs. This epidote is always associated with a large amount of very coarse-grained specularite. A similar increase in the amount of hematite and epidote is observed in passing southwest from the King shaft towards the Rainbow claim, and in this vicinity the concentration of these two minerals is quite remarkable. The tuffs are veined with them and numerous large spherical nodules are formed which usually have the hematite crystals assembled in their centers.

Closely associated with the King vein and located only 500 feet to the north is the Rainbow vein. It runs in a southwest direction towards the west showing of the King vein. This deposit consists of a network of small veins 2 or 3 inches in diameter, which run promiscuously about the ridge but which have a general trend in the direction of the south 45 degrees west and pointing towards the west showing of the King vein. In places the veins are confined to the joint plains and bedding.

These veins contain quartz, epidote, hematite, chalcopyrite, magnetite, zinc blende and a white mineral associated with the zinc blende believed to be a silver mineral.

The most plentiful mineral is the hematite which is in the form of a very coarsely crystalline specularite and, besides occurring in the ore veins, is plentifully distributed through the country rocks for a considerable distance from the veins. Samples of it collected by Robertson[2] assayed: copper, 6.7 per cent.; silver, 36.8 oz.; gold, 0.88 oz.; and copper, 6.6 per cent.; silver, 58 oz.; gold, 1.68 oz. per ton. A number of specimens of this specularite were examined under the microscope, both the metallographic and the petrographic. The thin flakes which cleave off easily, when mounted in sealing wax and cleaned with a chamois, make excellent preparations for the reflecting microscope. All of these that were studied were found to be perfectly homogeneous under the oil-immersion lens. Polished sections were also examined and in a few, chalcopyrite was found interlaminated with the leaves of hematite, but only in minute quantities. The preparations studied under the petrographic microscope transmitted a brownish-red ray, showed no pleochroism, and a very weak double refraction. They also appeared perfectly homogeneous. In view of these facts it is very difficult to explain the presence of so much silver and gold, unless the samples taken by Mr. Robertson contained also a considerable amount of magnetite. Magnetite is almost as plentiful as hematite, and is associated with numerous specks of copper sulphides and silver minerals. The zinc blende is also a peculiar type, and occurs in flat lenses in the quartz associated with chalcopyrite. It is quite transparent when poilshed, but when taken from the vein is coated over with a thin black film, which, with its well-developed cleavage, gives it the appearance of hematite. The zinc blende is highly impregnated with chalcopyrite and the white mineral already referred to. The chalcopyrite is fresh and homogeneous and replaces the hematite and zinc blende. Bornite was seen in only one specimen and there in very small amounts.

Oxidation has produced a considerable amount of limonite and a little covellite.

These metallic minerals were associated with quartz and large quantities of epidote. The quartz has preceded hematite which

[2] Robertson, W. Fleet, Annual Report of the Minister of Mines, British Columbia, 1905, p. J–126.

		King.						Rainbow.
		Pit 1.	Pit 2.	Pit 3.	Pit 4.	Pit 5.	Pit 6.	
		East end					West showing	
First period	Primary	Quartz Pyrite Arsenopyrite Chalcopyrite Zinc blende Tetrahedrite	Quartz Pyrite Arsenopyrite Zinc blende Chalcopyrite Tetrahedrite	Quartz (small amount) Chalcopyrite Bornite Tetrahedrite	Quartz Chalcopyrite Bornite Tetrahedrite	Quartz Bornite Tetrahedrite Magnetite Chalcopyrite	Quartz Chalcopyrite Bornite Tetrahedrite	
	Secondary			Covellite Malachite	Covellite Malachite	Covellite Malachite	Covellite Malachite	
Rock alteration		*Chlorite* Epidote	*Chlorite* Epidote	*Chlorite* Epidote	*Chlorite* Epidote	*Chlorite* Epidote	*Chlorite* Epidote	
Second period	Primary				Quartz ? Hematite Magnetite	Quartz Hematite Magnetite Chalcopyrite	Quartz Epidote Hematite Magnetite Chalcopyrite	Quartz Epidote Hematite Magnetite Chalcopyrite Zinc blende Tetrahedrite
	Secondary				Hematite ? Limonite	Hematite Covellite Malachite Limonite	Hematite Covellite Malachite Limonite	Hematite Limonite Malachite Covellite
Rock alteration					Chlorite *Epidote*	Hematite *Epidote*	Chlorite *Epidote*	Chlorite *Epidote*

replaces it, but the epidote is associated with the hematite in a manner which suggests a nearly simultaneous deposition of both minerals.

The country rock consists of tuffs which, when not altered, are a bright red color. Near the vein they are highly epidotized and silicified, and impregnated with coarse hematite. This zone of intense epidotization surrounds the deposit for several hundred feet, extending over to the King vein in its western part.

Summary of the King and Rainbow Veins.—The significant facts brought out in the observations on these veins are:

1. The King vein has the typical structure, rock alteration, and mineral composition of the other veins surrounding the granodiorite stock, and thought to be genetically connected with it.

2. The Rainbow vein has all the characteristics of the other type of mineralization, such as the abundant development of chalcopyrite, hematite and epidote.

3. As the King vein approaches the Rainbow, and comes within the region which was effected by late mineralization, the minerals characteristic of this period begin to appear in increasing amounts in the King vein and are seen replacing the bornite and tetrahedrite of the earlier period. At the extreme west end where the two veins come almost together the earlier minerals are almost completely obliterated by the chalcopyrite and hematite of the later period.

These facts are in strict accord with the theory which explained similar conditions in the Excelsior and High Grade veins. That is, there were two periods of mineralization, one following the intrusion of the granodiorite stock which produced the bornite-chalcopyrite ore, and one following the intrusion of the Bulkley eruptives which developed the chalcopyrite-hematite ore. The Excelsior and High Grade veins were effected throughout by both periods of mineralization owing to the proximity of the dikes, while only part of the King vein is effected by the late mineralization.